CHAPTER 3
POPULATION EFFECTS DUE TO PM EXPOSURES

This chapter describes the Agency's estimates of population effects due to exposures to airborne particulate matter (PM) from cement kiln dust waste management units. In Section 3.1 EPA provides the background and starting point of this analysis, discussing what specifically is not included in the scope of the analysis and any resultant implications. Section 3.2 presents a summary of the approach used to estimate the population effects. Section 3.3 includes a discussion of the results. Finally, Section 3.4 presents a discussion of the major limitations and uncertainties associated with the PM exposures analysis.

3.1 BACKGROUND AND SCOPE

The objective of this analysis is to estimate the risks to populations exposed to airborne particulate matter released from CKD waste management units at cement facilities. These risks, more appropriately termed effects, are characterized in terms of the number of people in the populations surrounding the cement facilities that are exposed to PM concentrations above certain thresholds. (As explained below, the impacts due to exposure to PM cannot be calculated in conventional terms of risk, such as the probability of an individual expressing certain health effects or the number of cases of certain illnesses occurring within the exposed population.)

3.1.1 Starting Point of this Analysis

The Agency first analyzed PM_{10} (particulates with an aerodynamic diameter less than or equal to a nominal 10 micrometers) concentrations at cement plants as part of the *Notice of Data Availability on Cement Kiln Dust* (NODA). This analysis expanded the original risk modeling conducted for the *Report to Congress on Cement Kiln Dust* (RTC) by determining the concentration of airborne CKD particulates at a given exposure location (i.e., closest agricultural field, nearest residence, and CKD pile boundary, as well as residences located at five concentric rings surrounding the facility extending to 10 kilometers) for each of five case-study facilities. The methodology and results of this analysis are presented in the *Technical Background Document* for the NODA. Releases from CKD piles were simulated using the landfill simulation component of MMSOILS. Each of the CKD piles at the five facilities was simulated as an unlined and uncovered landfill unit. MMSOILS employs one empirical model to estimate the annual average release rate of PM_{10} due to wind erosion. Due to the nature of this screening analysis, the Agency did not use a complete set of meteorological data or stability array in the atmospheric dispersion modeling. Rather, the Agency used a single set of meteorologic conditions to represent a conservative estimate of annual average ambient concentrations in any direction surrounding the site. The results of this initial PM_{10} analysis consisted of annual average PM_{10} concentrations, for both the best estimate and upper bound modeling scenarios, for the five case-study facilities originally modeled by the Agency.

The Agency later expanded its PM_{10} analysis of the five original case-study facilities to the entire sample of 82 cement plants addressed in the NODA. The methodology and results of this expanded analysis are presented in the *Technical Background Document on Potential Risks of Cement*

Kiln Dust in Support of the Cement Kiln Dust Regulatory Determination. Having determined that pile size, wind speed, and exposure distances were the parameters that influenced PM_{10} concentrations the most using the MMSOILS model, the Agency performed a number of MMSOILS runs to estimate PM_{10} concentrations for eight different pile sizes and nine different distances, which were based on the pile sizes and exposure distances reported for the sample of cement plants examined. The Agency also performed four additional MMSOILS runs changing only the wind speed to reflect the minimum reported wind speed, the average reported wind speed, the maximum reported wind speed, and an additional wind speed between the average and maximum reported wind speeds. The Agency then developed adjustment factors to account for the differences in the PM_{10} concentrations using the average wind speed and the three other wind speeds. To address the large variability in pile size, wind speed, and exposure distance at the sample facilities, the parameters at the individual sample facilities were matched with the closest modeled parameters to eliminate having to model each individual facility. The resulting PM_{10} concentrations presented in this analysis provide a best estimate of the PM_{10} concentrations at each individual facility.

3.1.2 What is Included and Excluded from the Scope of this Analysis

In the expanded analysis that was conducted for the Cement Kiln Dust Regulatory Determination, MMSOILS (an EPA multimedia fate and transport model) and a simplistic modeling approach were used to create a matrix of PM concentrations for various CKD pile sizes and receptor distances. PM_{10} concentrations at each of a set of 52 facilities were then estimated – for exposure points defined by the facility boundary and the closest residence – by selecting the pile size-receptor distance combination from the table that best represented the facility's actual conditions, and scaling the table value up or down based on differences between the wind speed at the facility and the wind speed assumed in the modeling. For the current modeling exercise, EPA used a more sophisticated model and approach to estimate PM_{10} as well as $PM_{2.5}$ concentrations under a broader range of conditions. In particular, the current exercise assessed releases of PM from other sources at the facility in addition to the CKD waste pile. A detailed comparison of previous and current modeling is provided in Appendix G. In brief, EPA used these new results to refine the PM estimates for the 52 facilities considered previously and to determine the number of nearby residents who are potentially exposed to ambient PM concentrations of significance. Furthermore, the modeling approach used in this analysis estimates the ambient PM_{10} as well as $PM_{2.5}$ concentrations due to only releases from the CKD waste handling and management. Thus, the approach does not account for background concentrations of PM_{10} and $PM_{2.5}$ that may be due to other sources.

As with the indirect exposures analysis, a total of 26 facilities have been excluded from this PM analysis because they could not be assessed directly given a lack of data. To account for these facilities, however, results from the facilities that were analyzed are extrapolated to the 26 facilities to derive a composite picture of potential population effects at the full universe of cement facilities (i.e., 108 facilities). In summary, from a grand total of 108 facilities, 82 can be viewed as having been analyzed. Of these 82 facilities, 30 were deemed to have negligible risks/adverse effects based on initial screening and the remaining 52 were analyzed in greater detail to characterize risks/adverse effects due to PM exposures. Finally, results from these 82 (i.e., 52 plus 30) facilities are extrapolated to the 26 facilities that were not analyzed due to lack of data.

3.2 SUMMARY OF OVERALL APPROACH

3.2.1 Identify An Appropriate "Risk Descriptor" for PM Exposures

Analyses conducted for the RTC and NODA have described to a large extent the nature of adverse effects from PM exposure. For this analysis EPA determined that the most appropriate risk descriptor would be one that described the extent of adverse effects in terms of the total number of people exposed to a specific level of PM. A review of EPA's 1996 staff paper on the airborne particulate matter standard[1] points to two conclusions that are key for this analysis:

(i) While coarse and fine particles can increase respiratory symptoms and impair breathing, the staff paper concludes that fine particles are more likely to contribute to the health effects described in a number of recently published studies on particulate matter exposures.

(ii) The staff paper recommends that, while retaining the coarse particles (i.e., PM_{10}) standard, more effective and efficient protection could be provided by establishing a separate standard for fine particles (i.e., $PM_{2.5}$).

Thus, for this analysis, the Agency characterized population effects in terms of exposures to both PM_{10} and $PM_{2.5}$. Because there are no widely accepted dose-response measures for PM exposures, EPA did not describe the population effects in conventional terms of number of excess disease cases. Instead, the Agency used the National Ambient Air Quality Standards (NAAQS) for PM as thresholds against which the facility-specific PM concentrations could be compared at any given receptor point. The Agency used both the annual average and the peak 24-hour average PM concentrations as the basis for risk estimation. The NAAQS used in this analysis are shown in the text box.

Standards Used in the Analysis

	PM_{10}	$PM_{2.5}$
Annual average NAAQS	50 ug/m^3	15 ug/m^3 *
24-hour NAAQS	150 ug/m^3	65 ug/m^3 *

* These represent PM standards announced by EPA on July 17, 1997.

3.2.2 Develop the Overall Modeling Framework

For efficiency, EPA's overall modeling approach consisted of (i) selecting the "highest-risk" facilities, (ii) modeling the emissions and dispersion at these facilities, (iii) predicting PM concentrations at exposure points for which population data can be overlaid to predict population effects at the highest-risk facilities, and (iv) using these results to draw broader conclusions for

---

[1] *Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information.* Office of Air Quality Planning and Standards Draft Staff Paper, April 1996.

facilities that were determined to be of "lower-risk." The Agency used the term "highest-risk facility" here to mean a facility that, among a group of facilities that would experience relatively similar dispersion patterns, is the one with the highest emissions from all relevant sources and therefore would result in highest ambient concentrations of PM at receptor points.

To select such highest-risk facilities, EPA first created groups of facilities that are expected to experience relatively similar atmospheric dispersion patterns, and then identified within each group the single facility with the highest emissions potential.

Both emission and dispersion of dust particles are heavily dependent on the climate and meteorological conditions at a given facility. As evidenced in some preliminary modeling of cement facilities that the Agency had conducted, the factors that most significantly influence the dispersion of airborne PM from the source of their emissions include the following:

- wind speed,
- deviation in wind speeds,
- stability class,
- mixing height, and
- source/receptor distance.

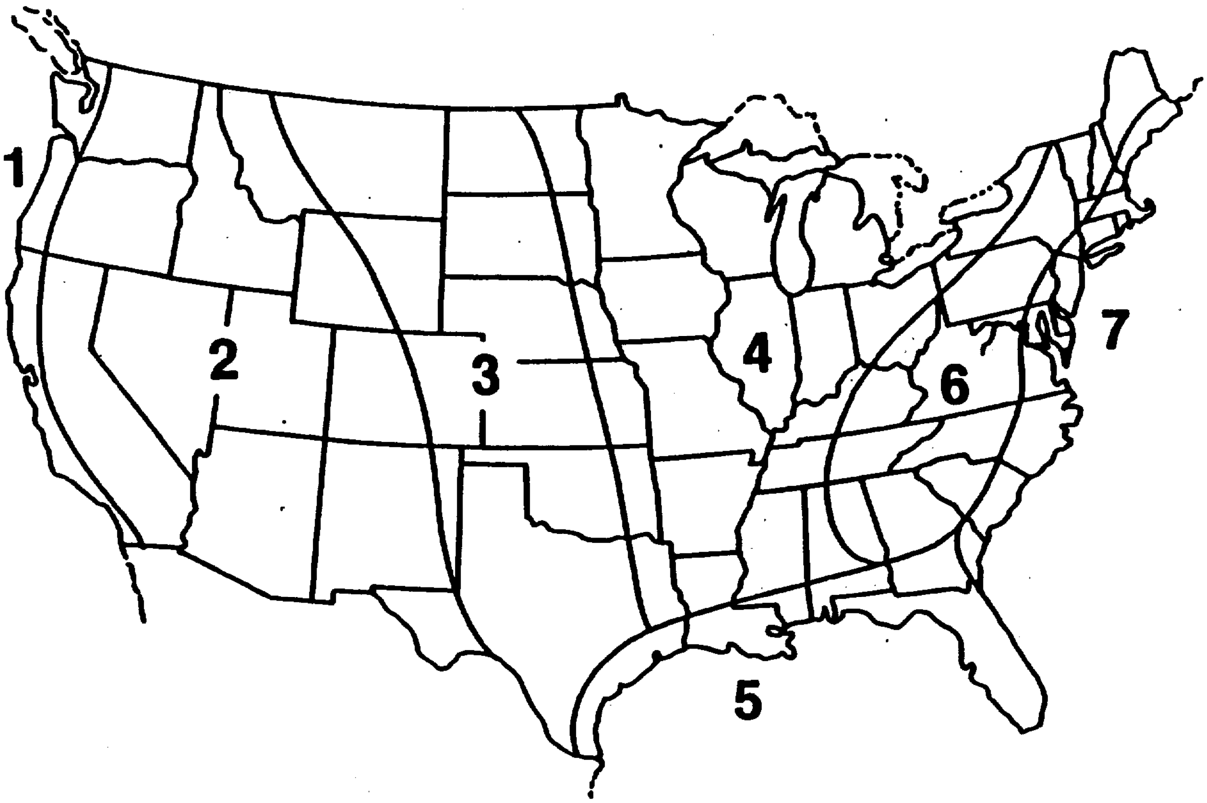
All of these factors or variables are determined by the climatic conditions in the particular geographic region where the facility is modeled. Thus, to account for the influence of climate and meteorology on dispersion modeling, EPA used an approach that divides the continental United States into seven climatic regions. Region numbering starts at the west coast and ends at the east coast as shown in Exhibit 3-1. (This approach of dividing the continental United States into seven climatic zones is recommended in *Rapid Assessment of Exposure to Particulate Emission from Surface Contamination Sites* (U.S. EPA, September 1984)). The underlying assumption for this approach is that all facilities that fall within the same region are subject to generally similar dispersion patterns.[2] The seven climatic regions were used for grouping purposes only – the highest-risk facility was selected from within each of the seven climatic regions and then actual meteorological data were collected for the individual facilities modeled.

EPA's general approach to selecting the highest risk (or high emissions) facilities was, first, to identify the parameters that in combination have the greatest influence on emissions, and, second, to compare the actual facility-specific values for those parameters among the facilities in each climatic region. The relevant parameters, actual values used, and facilities selected based on such comparisons are discussed in detail in Section 3.2.5 of this chapter. In general, however, it should be noted that these parameters are both operational (tons of CKD dust wasted/year) and meteorological (average wind speed, fastest mile, and the number of days with > 0.01 inches of rain) for each facility. Thus, the framework of dividing the country up into climatic zones also helps to simplify the determination of high emissions facilities.

---

[2] Factor analysis was used to examine interrelationships between wind speed/wind direction, precipitation, and mixing height data from 59 National Weather Service stations. The climatic zones were defined based on the results of the factor analysis combined with examination of other climatological information.

Exhibit 3-1
Climatic Regions



Source: *Rapid Assessment of Exposure to Particulate Emission from Surface Contamination Sites*, U.S. EPA, September 1984.

Once the highest-risk facilities were determined, site-specific operational and meteorological data were used with an air quality dispersion model to predict PM concentrations for a grid of receptors surrounding the facility. These results were then combined with actual population data to determine the number of people exposed to levels of particulates below the NAAQS and above the NAAQS, for the highest-risk facilities. Because the populations located around the highest-risk facilities were expected to be exposed to concentrations resulting from emissions that are much higher than that emitted at other facilities within the climatic region, and because the facilities should have similar dispersion patterns, these results were used to draw conclusions regarding the lower risk facilities.

3.2.3 Select Model(s) for Estimating Emissions and Dispersion

The Agency evaluated the tradeoffs of several modeling approaches and tools that can be used for assessing population exposures to PM, and chose the most tractable approach given the study design and objectives. Compared to the previous modeling effort for the RTC and NODA, PM modeling for the current analysis was much broader, especially in three areas: (i) including emissions from other sources in addition to the CKD waste pile, (ii) using a dispersion model that uses more refined meteorological data and that can possibly account for "terrain effects" (e.g., the effects of disposing of CKD in a quarry) and (iii) predicting exposure concentrations within a grid that includes multiple receptor points around the facility.

Emissions Modeling

Emissions were estimated using methods and equations from EPA's *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, Fifth Edition* (commonly referred to as *AP-42*). The methods presented in *AP-42* for estimating fugitive dust emissions are principally compiled from *Control of Open Fugitive Dust Sources* by Cowherd et. al. (1988), which was used as a supplemental reference. *AP-42* contains the emission estimation methods and equations recommended for use by the EPA Office of Air Quality Planning and Standards. It is the best approach available, short of conducting new field studies to measure emissions. As noted in *AP-42*, significant atmospheric dust arises from the mechanical disturbance of granular material exposed to the air. Dust generated from such open sources is termed "fugitive" because it is not discharged to the atmosphere from a confined point source (stack). Common sources of fugitive dust include wind erosion from CKD piles, aggregate handling (e.g., loading and unloading), unpaved road travel, and bulldozing of CKD. For these sources, the dust-generation process is caused by two basic physical phenomena:

(1) Pulverization and abrasion of surface materials by application of mechanical force through implements (wheels, blades, etc.), as usually occurs during aggregate handling; and

(2) Entrainment of dust particles by the action of turbulent air currents (from passing vehicles or high winds) from exposed, disturbed surfaces.

Emissions due to both mechanical abrasion and wind erosion were modeled by EPA; the specific sections covering the equations and other background information has been extracted from *AP-42* and included in this document as Appendix F.

Dispersion Modeling

Several candidate dispersion models/modeling approaches that EPA evaluated are described below:

Option 1: Use the Fugitive Dust Model (FDM), which is specifically designed to estimate concentration and deposition impacts from fugitive dust sources. One of the unique characteristics of fugitive dust sources, such as CKD piles, is that emission rates are a function of the wind speed. FDM has the advantage of incorporating hourly wind speeds into calculations of both the pile emission rate and subsequent downwind dispersion. Also, FDM can accept hourly meteorological data output from the EPA RAMMET meteorological pre-processor program. If a threshold wind speed is specified for emissions, FDM has the capability of examining each hour of meteorological data to determine whether the wind speed is above or below the threshold, and then turn the emissions "on" and "off" based on these wind speeds. Furthermore, FDM can relatively easily incorporate emissions from both area, volume and line sources, which is particularly important for modeling unpaved/paved road sources. The main disadvantage of FDM is that it does not handle terrain effects, which could have a significant influence on site-specific results. A secondary disadvantage is that source-specific contributions to predicted concentrations are not available directly from normal model operation.

Option 2: Use the Industrial Source Complex 3-Short Term (ISC3ST) model. The ISC3ST model is recommended in the EPA Guidelines on Air Quality Models for dispersion modeling of complex industrial source facilities. (The model is included in Appendix A of the Guidelines, which describes EPA-preferred air quality models.) Like the FDM, the ISC3ST model can accept hourly meteorological data (e.g., stability class, wind direction) to predict hourly, 24-hour, or annual average concentrations. ISC3ST, however, has the advantage of accepting and processing terrain elevations for both emission sources and receptor points. ISC3ST, which cannot input line sources, can be used to simulate roadways sources by breaking up the roadway into consecutive rectangular area sources. ISCST also has the advantage of automatically generating data on source contributions.

Option 3: Use the ISC3 Long Term (ISC3LT) model. As with ISCST, ISCLT is recommended in the EPA Guidelines on Air Quality Models, and can incorporate terrain elevations and source contributions. ISCLT, however, uses a Joint Frequency Distribution (JFD) or Star data set of meteorological data, not a complete set of hourly meteorological data. The Star data represent annual meteorological data, and this cannot be used to estimate concentrations for periods less than a year (e.g., 24-hour average concentration) without using period adjustment factors.

Option 4: Use the SCREEN model. Even though the SCREEN model uses many of the same dispersion equations and source representations used in the ISC3ST model, it is limited to operating for one source at a time and worst-case meteorological data. Actual data from the facility location cannot be incorporated into this modeling approach.

Given this information, EPA selected the ISC3ST modeling approach because (1) terrain effects could be considered, (2) ISC3ST could discriminate between airborne particulate concentrations that are due to emissions from the pile versus those from the handling train, and (3) a year's worth of actual hourly meteorological data could be included in the modeling. Also, as mentioned above, line sources, such as unpaved roads, could be modeled as a string of elongated area sources. The advantages gained in terms of handling wind-related emissions sources by using the FDM model are not significant in this application due to the low wind speeds needed to entrain cement kiln dust. Such wind speeds are low enough that potential emissions can occur during typical wind speeds. The Agency did not use the ISCLT or SCREEN approaches which are simpler than FDM or ISC3ST, because the modeling will not have been a significant improvement over what has been done previously. Furthermore, more extensive model runs would have been required to estimate concentrations at multiple receptor locations.

It is difficult to state with any certainty how the new modeling results compare with those generated for the NODA using MMSOILS. Because EPA used a more refined approach (compared to a conservative screening approach), concentrations of PM_{10} at the facility boundary and the nearest resident tended to be lower based on the new modeling, although this result is not unequivocal. The new modeling did, however, provide an indication of how the low and high concentrations are distributed spatially around the facility. A discussion of the current versus the previous modeling approaches is provided in Appendix G.

3.2.4 Determine Sources of Emissions

In this step EPA defined the sources or source types from which emissions were to be estimated for the modeled facilities. The previous modeling efforts had assumed that all or a great majority of the PM emissions result from the CKD waste pile[3] at a given site. Thus, emissions from only waste piles were included in the previous modeling. For the current analysis EPA first determined whether, in addition to the waste pile, significant amounts of PM emissions could result from the "handling train" associated with transporting and handling the CKD from the point of generation to the point of disposal at the facility.

The general "handling train" is defined as consisting of the following elements of the baseline CKD disposal practice: loading, transport, unloading, interim storage pile, and moving into the pile/monofill. For most of the facilities to be modeled, there was very little facility-specific information available on how exactly the CKD is handled between collection at the facility and disposal at the pile (e.g., pelletized prior to transport). EPA consulted several sources (e.g., site visit trip report, PCA surveys, data collected for the NODA) in an effort to determine which elements of the handling train would be present at the particular facilities. Ultimately, instead of using facility-specific information on the handling train, which was scarce, EPA assumed that the general handling

---

[3] EPA uses the term "waste piles" here to generally refer to wastes accumulated in piles, quarries, and landfills.

train scenario was applicable at all facilities. The Agency did, however, modify the specific elements constituting the train at each modeled facility based on whatever data were available (e.g., interim storage pile may not be relevant for all sites to be modeled).

3.2.5 Identify and Develop Data for Modeling Inputs

Emissions

Inputs needed to calculate particulate emissions from the handling train and the CKD pile include data on amount of material handled, the CKD transport truck, the road traveled, and inherent CKD properties. For each facility, the various parameters and their respective values are summarized below and presented in table form in Exhibit 3-2 (the facilities are organized in the table by climatic region). Included below is a discussion of the input parameters, their values, the data sources, and the role each input plays in the emissions modeling calculations for each source type.

Emissions - Aggregate CKD Handling

Emissions are calculated for each of the CKD loading and unloading steps in the handling train. Required as input for this equation (see Appendix F for the full equation) is the moisture content of the CKD, the mean wind speed, and the amount of material handled. For the highest-risk facilities modeled, the facility surveys were consulted and none indicated that the facility adds moisture to the CKD prior to transport. Therefore, the lower limit allowed by the emissions equation was used (i.e., 0.25 percent moisture). Mean wind speed and data on the amount of material handled were determined from facility-specific information.

Emissions - CKD Transport (on Unpaved Roads)

During transport, the abrasive nature of tires causes dust to be generated and then emitted from the roadway shoulders due to turbulence generated by vehicle movement. The necessary input parameters to model this emissions source include the truck data, roadway information, and the information regarding the level of activity of the trucks on the roadway, as outlined below.

Data required for the truck include:

- the empty weight of the truck (21 tons),
- the number of wheels on the truck (10),
- the vehicle driving speed (20 miles per hour), and
- the weight of the truck loaded with CKD (34 tons).

These truck parameters were estimated from brochures on trucks used in hauling operations (weights/wheels/capacity) and site visits (speeds). The capacity was derived by adjusting the truck payload capacity for the difference in density between soil (the normal payload) and CKD (the payload used in this modeling exercise). The value for the truck weight when carrying CKD also includes the assumption that the truck is only filled to 75 percent of total capacity in order to prevent CKD from spilling during transport.

Exhibit 3-2
Values for Parameters that Affect Emissions from Cement Facilities

	Name	File #	Climatic Region	Handling/ Controls at pile	CKD Unit Exposed Area (m^2)	Length of Side (x)	Length of Road One Way (mi)	Total CKD Wasted (mt/yr)	# Round Trips per Day	# Trips Over Same Area	80% of 2x	Percent of Total Area That is Disturbed	Annual Mean Wind Speed (m/s)		VMT per Day (mi)	Adjusted CKD Unit Area (m2)	Total Population within the Modeling Region	Distance (m) of Closest Block to the Plant	Population of the Closest Block
1	National Lebec	92	2	compacted	79,000	199	0.3	63,490	15.4	5	318.0	15	3.09		9.2	11,747	13	3,626	4
2	Holnam Tijeras	52	2	wetted, compacted	101,726	226	0.85	25,752	6.2	3	315.5	8	4		10.6	5,990	1,157	389	11
3	Ash Grove Foreman	4	2	compacted	77,760	197	0.57	32,633	7.9	2	360.8	5	3.53		9.0	5,407	1,741	1,582	5
4	Holnam Morgan UT	55	2	no info	46,452	152	0.75	17,318	4.2	2	224.2	7	3.66		6.3	2,621	295	1,199	11
5	Calif Portland	18	2	not compacted	39,265	140	0.57	20,092	4.9	1	243.8	5	3.89		5.6	2,457	111	1,653	4
6	Ash Grove Inkom	5	2	compacted	557	17	0.57	454	0.1	1	26.7	35	4.51		0.1	192	1,595	54	3
7	Holnam Ada	53	3	compacted	544,062	522	7	76,095	18.4	6	834.5	7	4.49		258.3	36,946	16,565	151	15
8	Holnam Laporte	45	3	compacted	121,449	246	0.57	77,471	18.8	6	394.3	15	5.81		21.4	17,772	5,182	1,004	4
9	Southdown Odessa	109	3	no controls	141,264	266	0.85	42,541	10.3	8	182.1	42	4.86		17.5	10,929	491	4,717	182
10	Southdown Lyons	105	3	watered, bulldozed, compacted	26,662	115	0.75	65,000	15.8	3	425.2	7	4.15		23.6	10,525	2,985	554	0
11	Texas Industries	112	3	wetted, compacted	25,919	114	1	115,971	25.0	5	184.7	26	3.71		50.0	6,986	7,439	1,296	17
12	Ash Grove Mt City	7	3	compacted	18,581	96	0.76	19,047	4.6	2	172.4	9	3.69		7.0	2,153	38	3,473	4
13	Capitol Aggregates	21	3	spray	23,226	108	0.2	21,463	5.2	2	154.2	9	3.71		2.1	1,709	111,996	609	394
14	Lafarge New Braunfels	71	3	compacted	23,226	108	1.5	9,614	2.3	1	146.3	8	3.71		7.0	1,327	11,705	137	1
15	Dacotah Rapid City	103	3	compacted	16,729	91	1.5	15,591	3.8	1	172.4	5	5.18		11.3	1,241	30,969	523	1
16	Lafarge Alpena	67	4	compacted	232,260	341	0.95	430,569	25.0	8	545.2	14	4.01		47.5	32,715	12,231	1,185	6
17	Ash Grove Chanute	6	4	compacted	205,309	320	1.2	60,049	14.6	5	512.6	9	4.31		34.9	17,910	10,022	800	12
18	Lafarge Paulding	69	4	no info	234,803	343	0.3	29,024	7.0	8	233.4	33	4.23		4.2	14,002	3,406	882	0
19	Lone Star Cape Gir	81	4	compacted	184,877	304	0.28	608	0.1	8	231.4	33	3.65		0.1	13,882	19,683	607	2
20	Medusa Charlevoix	86	4	not compacted	50,167	158	1	75,467	18.3	7	240.8	28	3.88		36.6	12,514	4,171	1,096	1
21	Continental Hannibal	27	4	not compacted	58,557	171	0.75	67,082	16.3	6	253.4	22	4.67		24.4	11,126	7,145	502	3
22	Ash Grove Louisville	8	4	no info	45,300	150	1	89,318	21.7	5	273.8	18	3.67		43.3	10,685	2,341	564	3
23	Holnam Clarksville	49	4	pelletized, sifted, bulldoze over cliff, compacted	42,548	146	0.38	214,505	25.0	2	548.2	4	4.67		19.0	9,258	622	652	3
24	Holnam Florence	46	4	no info	41,822	145	0.76	107,120	25.0	4	152.7	26	4.15		38.0	4,777	1,073	1,220	9
25	Essroc Speed	30	4	dump at edge, after 1 week bulldoze into quarry, compacted	51,095	160	1.7	28,296	6.9	3	212.6	12	3.82		23.3	4,379	8,910	224	6
26	Lone Star Greencastle	80	4	compacted	45,522	151	0.28	20,226	4.9	2	255.7	8	4.3		2.7	4,210	11,566	623	17
27	Essroc Logansport	31	4	compacted	35,302	133	0.38	35,404	8.6	5	105.7	48	4.3		6.5	4,148	6,419	1,204	20
28	River Festus	98	4	pelletized, compacted	18,208	95	0.3	53,777	13.0	1	486.5	2	3.65		7.8	3,503	4,644	1,276	43
29	Lafarge Sugar Creek	68	4	no info	51,840	161	1.5	435	0.1	2	241.4	6	4.54		0.3	2,841	29,965	620	1
30	Lehigh Mason City	73	4	compacted	32,342	127	1	8,616	2.1	1	257.6	4	5.12		4.2	1,855	22,844	1,223	29
31	Heartland Independ	41	4	compacted	27,123	116	0.25	1,868	0.5	1	203.5	5	4.31		0.2	1,465	1,518	262	4
32	Lone Star Oglesby	79	4	into pond	16,200	90	0.57	5,446	1.3	1	186.3	5	4.29		1.5	1,342	5,390	758	30
33	Lafarge Fredonia	66	4	wetted, compacted	8,733	66	0.6	67,438	16.3	2	86.6	18	4.31		19.6	1,051	3,212	403	22
34	Medusa Demopolis	63	4	not compacted	8,906	67	0.5	16,741	4.1	1	106.8	12	2.95		4.1	1,040	7,178	754	5
35	Lafarge Buffalo	64	4	compacted	5,855	54	0.17	20,861	5.1	1	144.0	6	4.52		1.7	1,037	978	707	31
36	Holnam Dundee	48	4	compacted	3,716	43	0.25	5,225	1.3	2	43.6	39	4.8		0.6	576	26,903	269	85
37	Holnam Artesia	50	4	quarry lake	3,624	43	0.33	8,367	2.0	1	69.0	13	2.63		1.3	497	389	1,239	6
38	Lafarge Grand Chain	122	4	no info	3,345	41	0.1	8,163	2.0	1	68.1	14	3.63		0.4	490	1,274	1,342	6
39	Lehigh Mitchell	74	4	compacted	1,487	27	1.25	22,695	5.5	1	65.4	14	3.82		13.8	471	5,729	421	32
40	Rinker Miami	97	5	compacted	10,219	71	0.25	907	0.2	1	114.4	8	4.58		0.1	823	56,949	1,622	1,146
41	Tarmac Medley	111	5	not compacted	6,040	55	0.25	8,641	2.1	1	87.9	10	4.58		1.0	633	31,255	1,257	4
42	Blue Circle Ravena	13	6	watered	200,671	317	0.38	26,657	6.5	6	300.8	17	4.19		4.9	12,074	9,513	166	4
43	Signal Mountain	102	6	no info	70,685	188	0.5	68,993	16.7	2	506.8	4	2.84		16.7	7,860	27,362	421	237
44	Lehigh Cementon	76	6	no info	83,600	204	0.25	32,652	7.9	3	327.1	7	3.15		4.0	6,214	3,709	130	1
45	Lehigh Union Bridge	75	6	no info	51,022	160	0.76	14,734	3.6	4	169.6	19	4.02		5.4	4,343	4,509	303	13
46	Roanoke Cloverdale	100	6	compacted	22,483	106	0.38	43,997	10.7	1	255.6	4	3.35		8.1	2,191	1,094	1,441	16
47	Southdown Knoxville	108	6	compacted	19,500	99	0.95	4,387	1.1	1	158.0	6	2.84		2.0	1,138	21,262	118	15
48	Independ Hagerstown	57	6	no info	3,716	43	0.5	12,954	3.1	1	69.0	14	3.4		3.1	520	49,560	419	42
49	Holnam Holly Hill	54	7	not compacted	91,282	214	0.53	153,398	25.0	8	341.8	22	3.83		26.5	20,509	1,559	2,168	13
50	Lone Star Nazareth	83	7	no info	80,407	201	0.25	25,418	6.2	2	320.8	6	4.03		3.1	4,744	22,191	333	20
[illegible]	[illegible]	[illegible]	7	wetted, compacted	437	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The input parameters for the road include:

- the silt content of the road,
- the distance traveled during each trip between the facility and the waste pile, and
- the amount of rainfall per year falling on the road.

The silt content of the road was assumed to be 20 percent, the upper limit allowed by the AP-42 equation, in order to reflect the fact that not only dirt is present on the roadway but also a significant amount of CKD deposited to on the road from previous trips. As for the length of the road, the distance from the facility to waste pile was determined by examining facility maps and choosing the most likely route from facility to pile. Maps provided in response to the PCA facility survey were used in conjunction with U.S.G.S. maps to determine distance. Data on the number of days/year with at least 0.01 inches of precipitation were gathered from climatological data sources.

Roadway activity information, (the number of trips per day) was calculated as the amount of CKD wasted each day divided by the CKD capacity of the truck (12.5 tons, for hauling CKD). The amount of CKD wasted each day is the annual amount of CKD wasted divided by the number of working days per year. For each facility, the amount of CKD wasted per year and the number of working days per year was taken from the respective facility's PCA survey.

<u>Emissions - CKD Pile Wind Erosion & Bulldozing</u>

Emissions from the CKD waste pile include emissions from (1) wind erosion, and (2) additional disturbance of the surface area of the pile. Emissions from wind erosion of exposed surfaces were estimated using the procedures outlined in *AP-42*, Section 13.2.5, for the interim and temporary storage piles and the area of the monofill disturbed during each loadout of CKD. Meteorological data and information on the CKD material, as weathered in the piles, and data on the amount of disturbances of the CKD material were used to estimate these emissions.

Erosion potential was calculated based on the fastest wind speed during the period between disturbances and the threshold friction velocity of the material. The "fastest mile" data from "Extreme Wind Speed at 129 Stations in the Contiguous United States" was used to calculate emissions for this analysis. This wind speed represents the mean annual fastest mile[4].

Threshold friction velocity data specific to CKD material was also needed for this study. This information was not available from literature or site-specific data.[5] Consequently, the threshold

---

[4] Analysis of historical meteorological data to determine mean daily fastest mile values for each facility and the subsequent use of these values to estimate emissions were beyond the scope of this effort.

[5] It is likely that additional field studies and/or wind tunnel measurements would be required to adequately quantify this parameter, as previous work in the field has not focused on collecting physical data needed to characterize air emissions of CKD.

friction velocity was estimated based on a graphical relationship developed by Gillette[6] between threshold friction velocity and the size of the aggregate distribution mode. This graphical relationship contains a logarithmic relationship between the two variables (i.e., the log of the aggregate size distribution mode is proportional to the log of the threshold friction velocity) and can be used to predict threshold friction velocities for particle size distribution modes between 0.1 and 100 millimeters (mm). Since CKD is predominantly less than 75 micrometers (μm) in diameter, the threshold friction velocity for the smallest distribution mode included on the graph (0.1 mm or 100 μm) was selected. However, the resulting threshold friction velocity, 0.25 meters per second (m/s), first appeared to be quite low relative to those reported in *AP-42* for use in the emissions equation. Furthermore, EPA believed that the natural tendency of CKD to crust when exposed to moisture will tend to increase the threshold friction velocity for weathered surfaces. After further investigation into the properties of soils with physical characteristics similar to those found in CKD piles, a value of 0.75 (based on data for silt loam soil) was chosen for the threshold friction velocity.

The pile area disturbed during each trip is calculated as a fraction of the total pile surface area. (The total pile surface area for each facility was obtained from data collected for the previous RTC and NODA analyses.) Note that the total surface area normally is not disturbed during day-to-day operations; that is, the majority of the CKD pile remains undisturbed and forms a crust which effectively eliminates PM emissions from that portion of the pile (after the initial erosion potential has been depleted). Only the disturbed (i.e., driven on) portion of the pile is a source of continuing PM emissions.

No specific data on the disturbed area are available for the facilities modeled in the present analysis; thus, EPA developed an algorithm to determine for each facility the portion of the total pile surface area that is disturbed on a daily basis. The variables of influence used were the total number of trips per day (which is determined by the amount of CKD wasted annually), and the total surface area of the CKD pile. First, for purposes of calculation, EPA assumed that the total pile at a given facility is in the shape of a rectangle with one of the sides equal to "X" and the other equal to "2X." Knowing the surface area of the pile, the value for X could then be derived. Next, EPA assumed that during a single trip of a truck driving on the pile to unload the CKD, the truck would travel up 80 percent of the length 2X, turn around and then drive back. Thus, the area covered during a single trip would be 2X multiplied by 7.2 meters (which is twice the breadth of a typical truck used in such operations). A further assumption employed was that no more than a third of the total trips within a day are over the same area of the pile. For example, if a facility had nine trips per day, three of them would occur over a (7.2 x 2X) m^2 area, the next three would occur over a fresh (7.2 x 2X) m^2 area, and the remaining over yet another (7.2 x 2X) m^2 area. The sum of all the three (7.2 x 2X) m^2 areas would then be counted as the total area disturbed.

Emissions for direct disturbance of the material (bulldozing) were also examined for a few facilities using equations for bulldozing of overburden from Table 11.9-2 of AP-42. These equations require information on the silt content and moisture content of CKD pile dust. Silt content was originally estimated to be 90%, based on the weight fraction of particles less than 75 μm (from Dust

---

[6] As cited in Cowherd, Jr., C., *et al.*, 1988. *Control of Open Fugitive Dust Sources*, EPA 450/3-88-008, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1988.

"G" from the article "Cement Kiln Dust Management: Permeability," Todres et al., Portland Cement Association, 1992).[7] However, since the material would have weathered and crusted somewhat, upon further examination, this value was decreased to 30%. In addition, since the CKD is allowed to weather prior to bulldozing, it was assumed that a moisture content of 15% exists in the large CKD piles prior to bulldozing.

Dispersion

For this modeling application, ISC3ST was set up using default regulatory options, as recommended by EPA guidance. Setting this option automatically selects the following:

- Stack tip downwash,
- Final plume rise,
- Buoyancy induced dispersion (BID),
- Default vertical potential temperature gradients,
- Use of the calm processing routine,
- Default wind profile exponents,
- The appropriate value for pollutant half-life (if needed), and
- The building wake effects algorithm (with building information).

EPA selected the "rural" or "urban" option for each facility modeled, as appropriate (use of this option incorporates either rural or urban mixing heights and dispersion factors into the analysis). For each of the modeled facilities, the meteorological input data for dispersion modeling came from the weather station closest to the facility and included the following information:

- year, month, day, hour (for each value),
- wind speed (m/s),
- wind vector (degrees),
- temperature (deg. K),
- stability category, and
- mixing height.

The anemometer height, longitude and latitude, and stations numbers for both the surface and upper air stations were required for development of the meteorological data file. Physical data on the locations and dimensions of the emission sources (e.g. U-T-M coordinates for the corners of the CKD pile) and receptors was also input to ensure that the emission sources were modeled as accurately as possible. Many of the CKD piles are located in depressed quarries, are partially blocked by nearby terrain, or are within an area of elevated terrain. Therefore terrain heights were input to ISC3ST for each of the sources modeled and for each receptor located around the facility.

---

[7] Todres, H., *et al.*, 1992. *Cement Kiln Dust Management Permeability.* PCA Research and Development Bulletin RD103T, Portland Cement Association.